

Development and Application of PM_{2.5} Interpollutant Trading Ratios to Account for PM_{2.5} Secondary Formation in Georgia



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2014 EPA Regional/State/Local Modelers' Workshop
Salt Lake City, Utah – May 21, 2014

Introduction

- Facilities applying for PSD air permits are required to model the impact of direct PM_{2.5} emissions (≥ 10 TPY) using AERMOD.
 - In addition, these facilities must account for the impact of secondary PM_{2.5} formation from precursor emissions (NO_x and/or SO₂ ≥ 40 TPY).
- AERMOD does not contain chemistry or aerosol formation modules
 - The secondary formation of PM_{2.5} cannot be modeled directly in AERMOD.

Interpollutant Trading Ratios

- Sources applying for permits in areas designated nonattainment for PM_{2.5} can offset emissions increases of direct PM_{2.5} emissions with reductions of PM_{2.5} precursors in accordance with interpollutant trading ratios (also called “PM_{2.5} offset ratios”) contained in the approved SIP for the applicable nonattainment area.
 - For example, an existing source can increase PM_{2.5} emissions by X tons in exchange for reducing SO₂ emissions by Y tons.

Equivalent Direct PM2.5 Emissions

- PM2.5 offset trading ratios can be used to account for secondary formation of PM2.5 in AERMOD.
- Convert SO₂ and NO_x emissions into “equivalent” direct PM2.5 emissions.
 - **100**:1 → 100 TPY SO₂ = 1 TPY direct PM2.5
 - **10**:1 → 100 TPY SO₂ = 10 TPY direct PM2.5
 - **1**:1 → 100 TPY SO₂ = 100 TPY direct PM2.5
 - **0.5**:1 → 100 TPY SO₂ = 200 TPY direct PM2.5
 - This is ~100% conversion of SO₂ to (NH₄)₂SO₄
- Lower PM2.5 offset ratios will produce more secondary PM2.5.

Secondary Formation in AERMOD

- Option 1: Add SO₂ and NO_x “equivalent” direct PM_{2.5} emissions to the actual direct PM_{2.5} emissions and run AERMOD
 - Allows for ratios that vary temporally
- Option 2: Calculate a percent increase in direct PM_{2.5} emissions due to the addition of SO₂ and NO_x “equivalent” direct PM_{2.5} emissions and scale the AERMOD output for actual direct PM_{2.5} emissions
 - Allows for ratios that vary spatially

EPA Memo – July 21, 2011

The general framework for developing PM_{2.5} offset ratios would include the following steps:

- 1) Define the geographic area(s).
- 2) Conduct a series of sensitivity runs with appropriate air quality models to develop a database of modeled PM_{2.5} concentration changes associated with reductions of direct PM_{2.5} emissions and PM_{2.5} precursor emissions.
- 3) Calculate the interpollutant offset ratios for PM_{2.5}.
- 4) Conduct quality assurance of the resulting ratios.

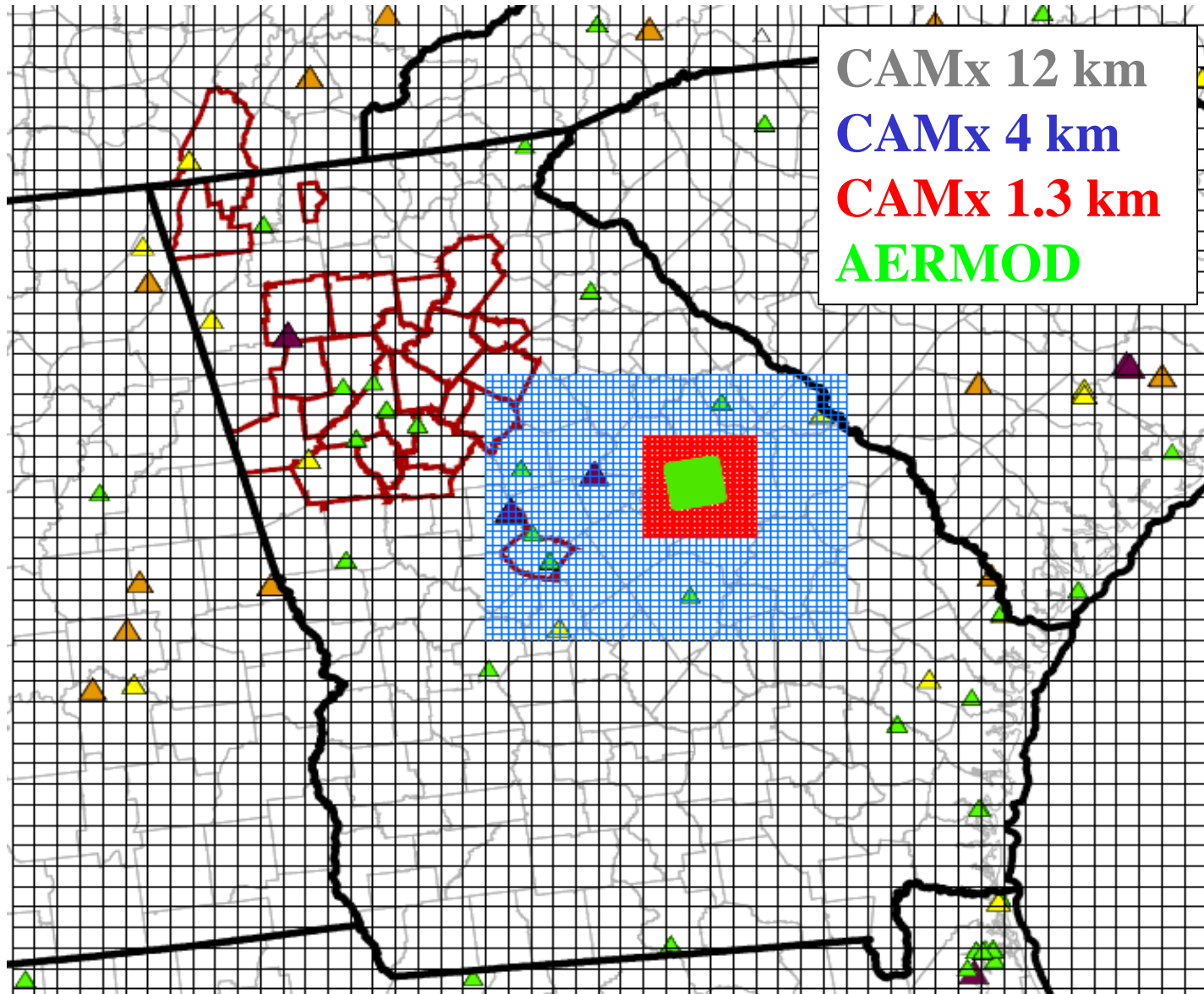
Case Study: Georgia

- Plant Washington
 - 850 MW Coal Fired Power Plant located in Washington County, GA
- GA EPD used CAMx photochemical modeling to account for secondary PM_{2.5} impacts and ozone impacts from the proposed facility.
- Final permit issued on April 8, 2010

Model Setup

- MM5 for Meteorology
 - VISTAS 2002
- SMOKE for Emissions
 - VISTAS 2009 used in Georgia PM2.5 SIP
 - Added power plant emissions
 - 4200 TPY SO₂, 1817 TPY NO_x, 6 TPY EC
 - Stack height = 137.16 meters
- CAMx with Flexi-nesting
 - 12-km/4-km/1.333-km
- Three sensitivity runs to calculate baseline PM2.5 offset ratios
 - Zero-out stack emissions: (1) SO₂, (2) NO_x, (3) EC

CAMx Modeling Domains



Modeled PM2.5 Offset Ratios

- Normalized Sensitivity (S)
 - $S_{\text{SO}_2} = (\Delta\text{PM}_{2.5\text{SO}_2} / \Delta\text{TPY}_{\text{SO}_2})$
 - $S_{\text{NO}_x} = (\Delta\text{PM}_{2.5\text{NO}_x} / \Delta\text{TPY}_{\text{NO}_x})$
 - $S_{\text{PM}_{2.5}} = (\Delta\text{PM}_{2.5\text{PM}_{2.5}} / \Delta\text{TPY}_{\text{PM}_{2.5}})$
- PM2.5 Offset Ratios (R)
 - $R_{\text{SO}_2} = S_{\text{PM}_{2.5}} / S_{\text{SO}_2}$
 - $R_{\text{NO}_x} = S_{\text{PM}_{2.5}} / S_{\text{NO}_x}$

Sensitivity Runs

- Sensitivity runs were performed to evaluate how PM_{2.5} offset ratios varied by:
 - Distance from the source
 - Season of the year
 - Stack height
 - Grid resolution
 - Location in the state

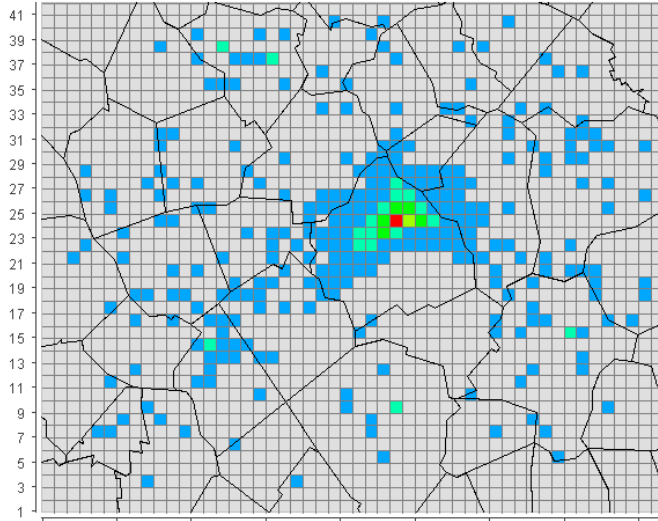
Trading Ratio vs. Distance

- **OPTION 1:** Average S_{SO_2} , S_{NO_x} , and $S_{PM_{2.5}}$ for all grid cells at a given distance, then calculate the average trading ratios (R_{SO_2} and R_{NO_x})
- **OPTION 2:** Calculate trading ratios (R_{SO_2} and R_{NO_x}) for each individual grid cell, then average for all grid cells at a given distance
 - A single cell with small $\Delta PM_{2.5_{SO_2}}$ or small $\Delta PM_{2.5_{NO_x}}$ can bias the results
- **GA EPD picked OPTION 1**

Δ PM_{2.5} – Annual EC and SO₂

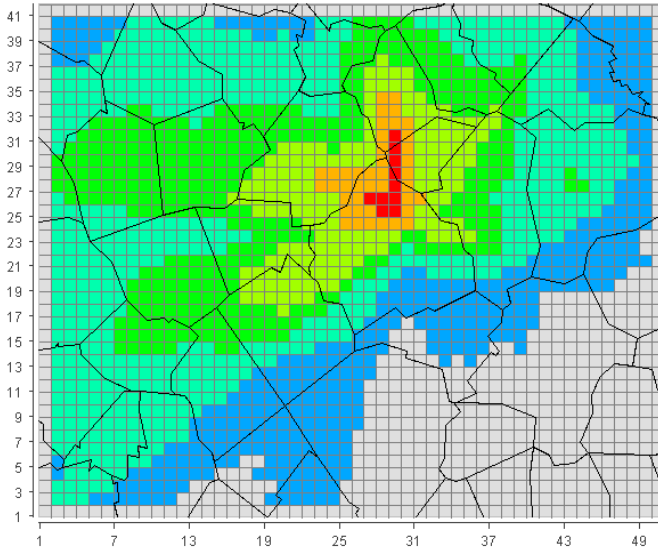
PEC Contribution

Annual Average, 1.333 km Domain

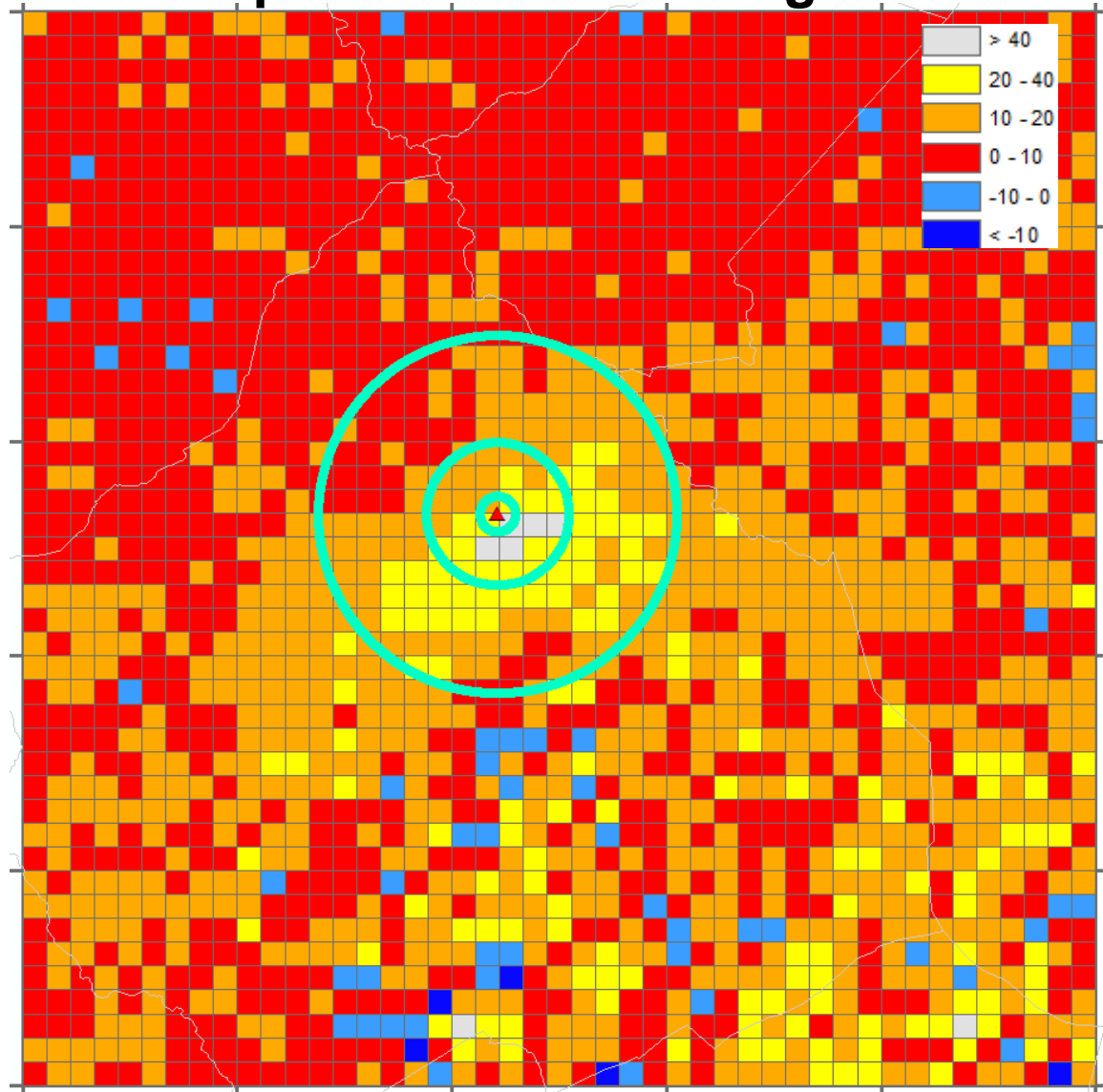


SO₂ Contribution

Annual Average, 1.333 km Domain



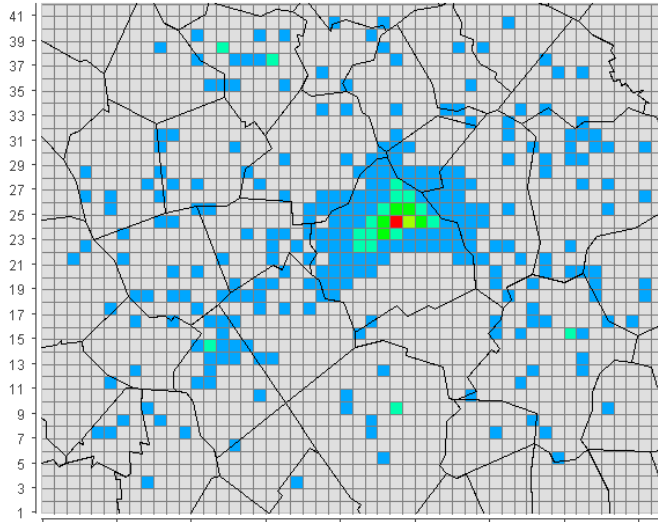
Option 2 - SO₂ Trading Ratio



Δ PM_{2.5} – Annual EC and NO_x

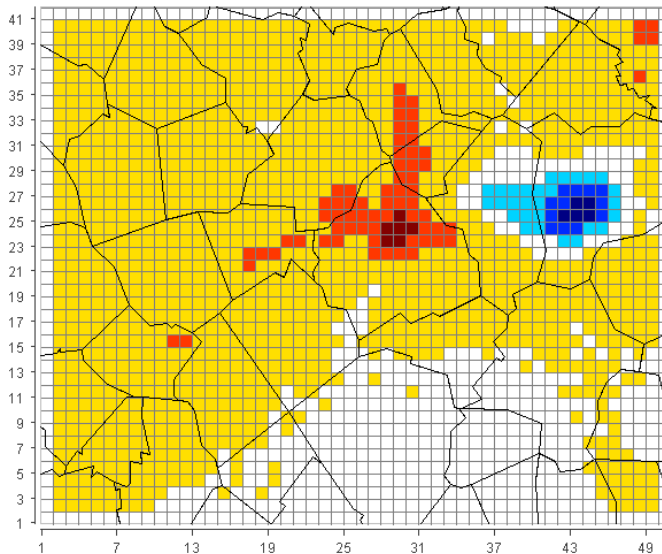
PEC Contribution

Annual Average, 1.333 km Domain

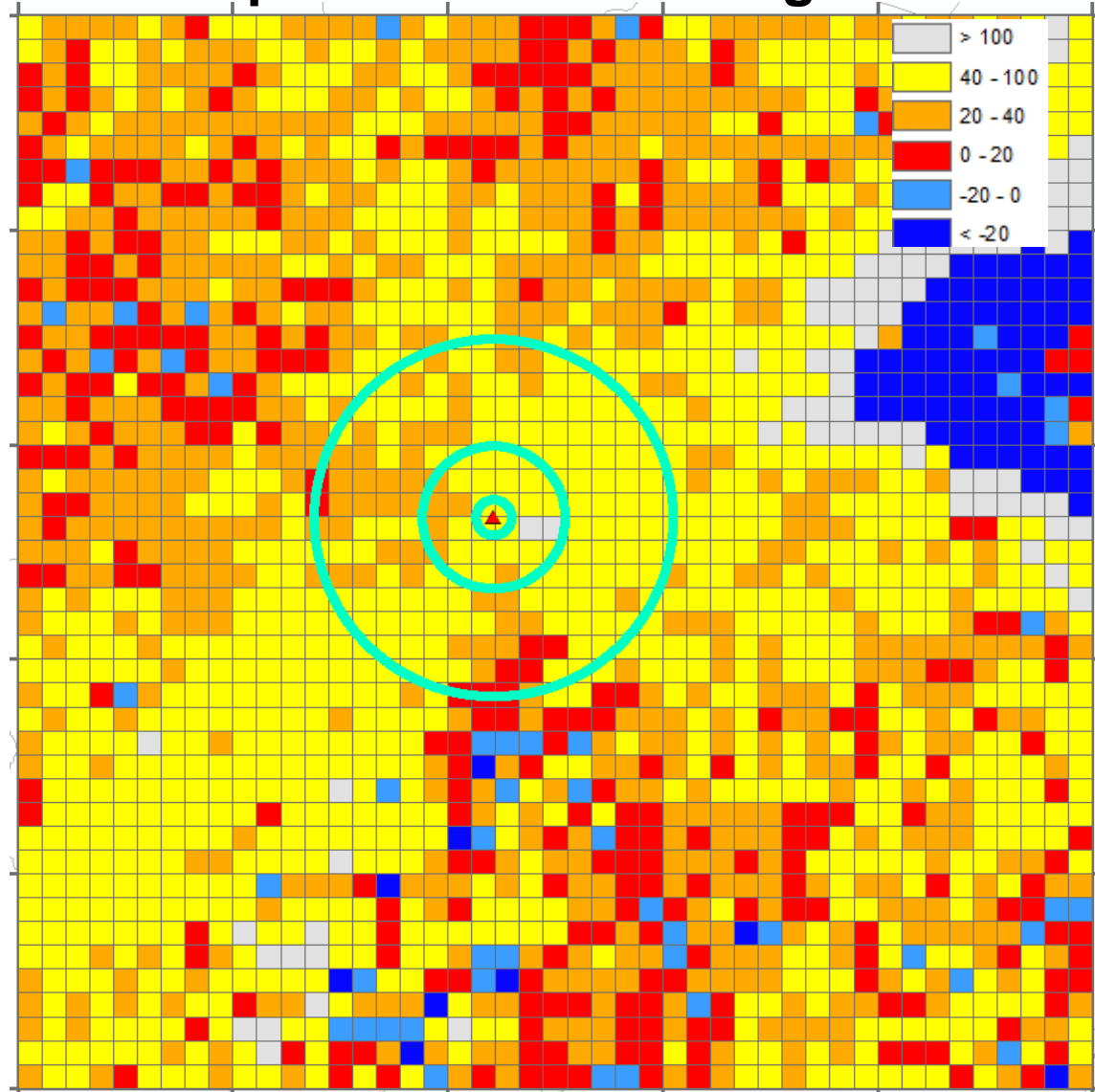


NO_x Contribution

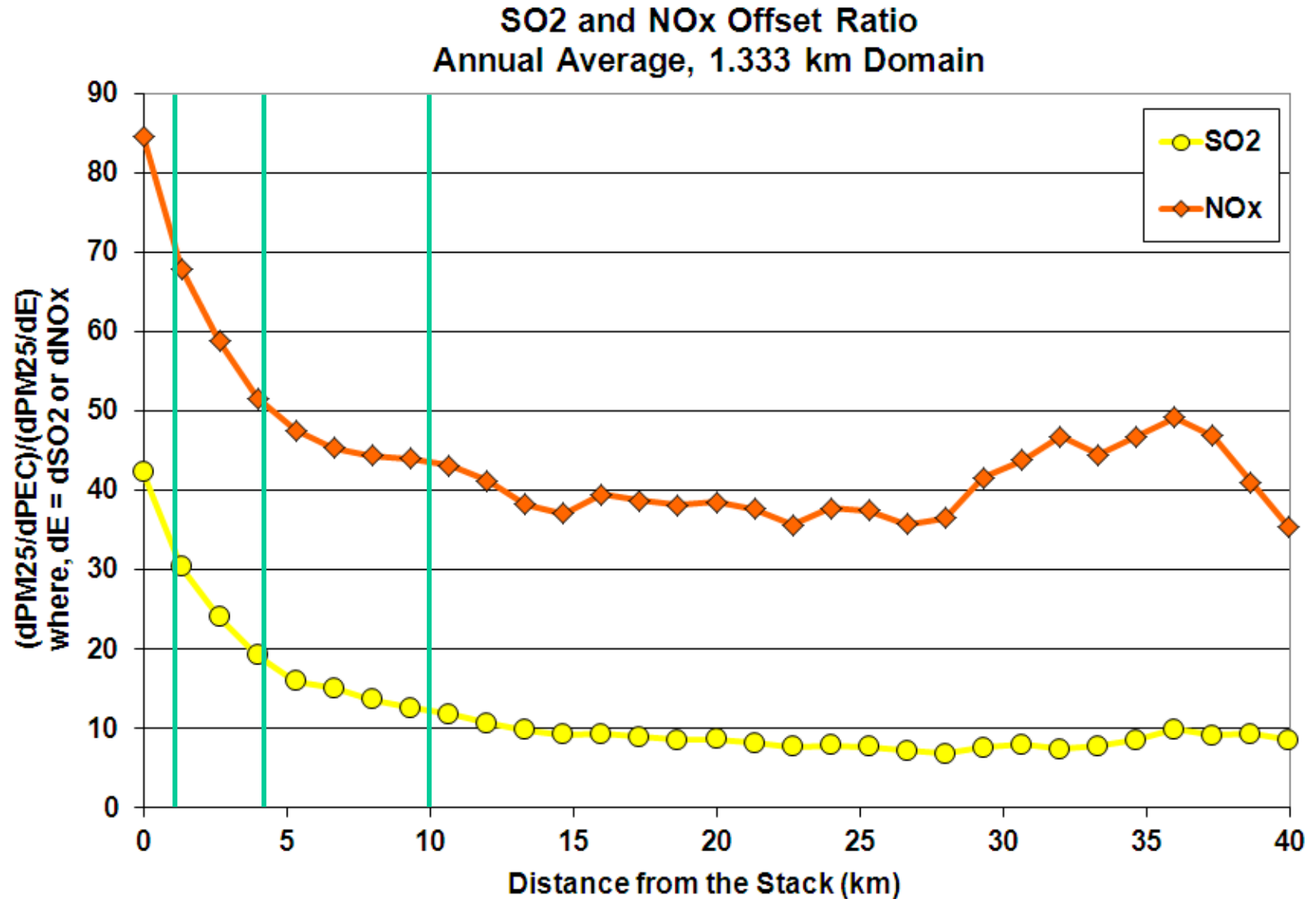
Annual Average, 1.333 km Domain



Option 2 - NO_x Trading Ratio



Annual PM2.5 Offset Ratios



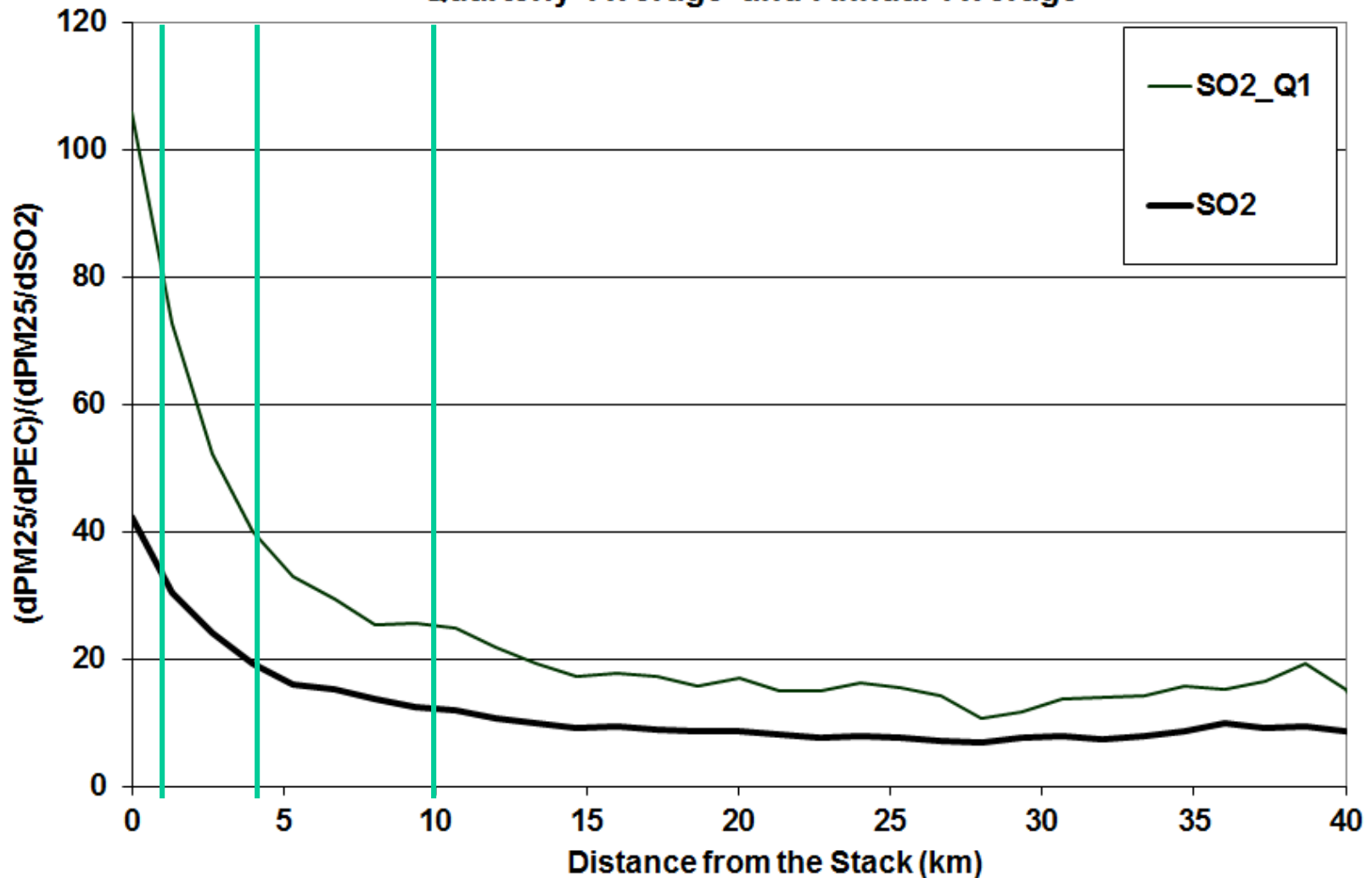
Distance from Source

- Lower PM2.5 offset ratio values are more conservative (i.e., each ton of SO2 and NOx will produce more secondary PM2.5).
- Select lowest ratio in each distance bin:

Distance	SO2 Ratio	NOx Ratio
< 1 km	30:1	70:1
1 – 4 km	20:1	50:1
4 – 10 km	10:1	40:1
> 10 km	7:1	35:1

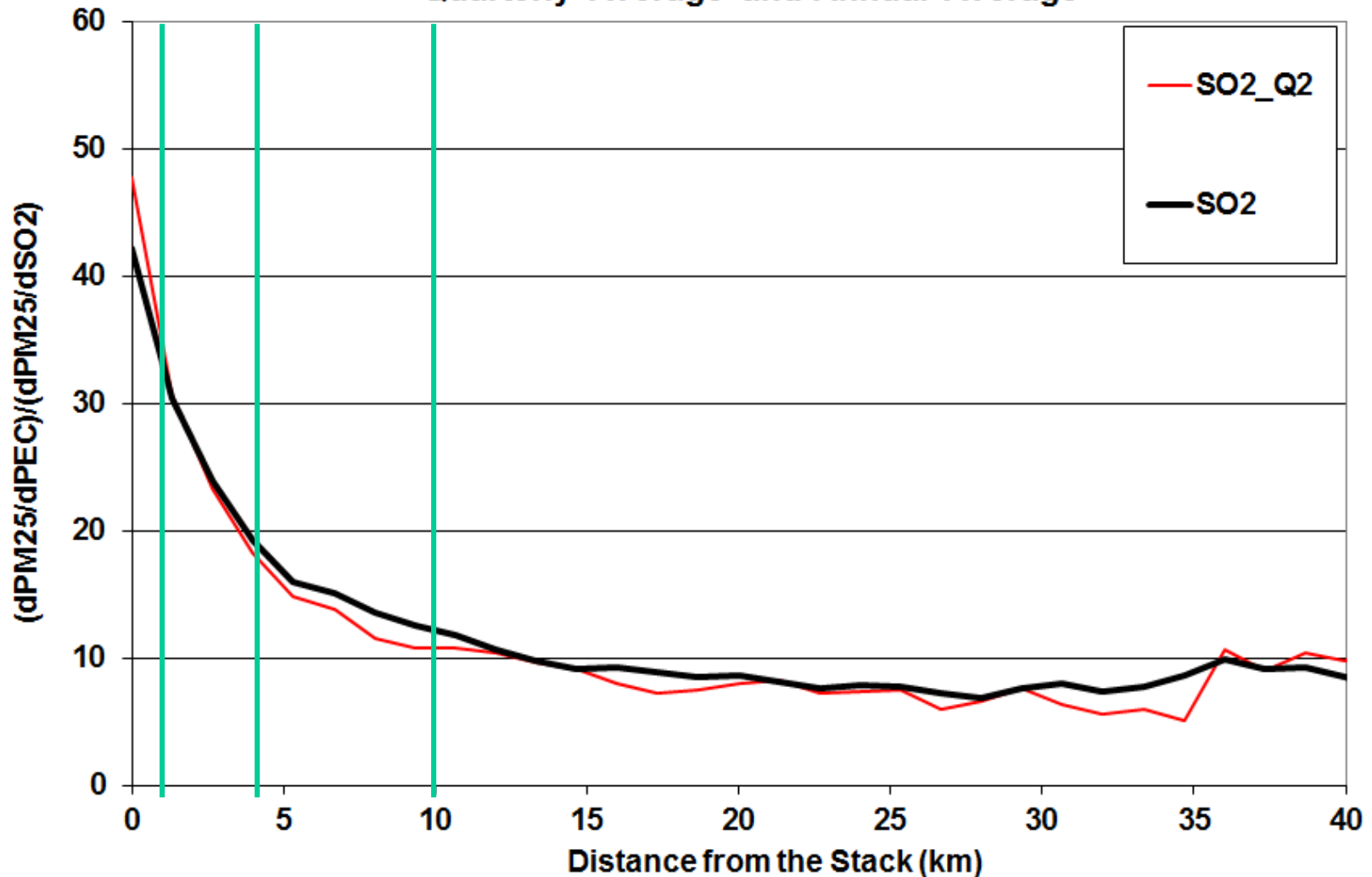
Q1 SO₂ Offset Ratios

SO₂ Trading Ratio at 1.333 km Domain
Quarterly Average and Annual Average



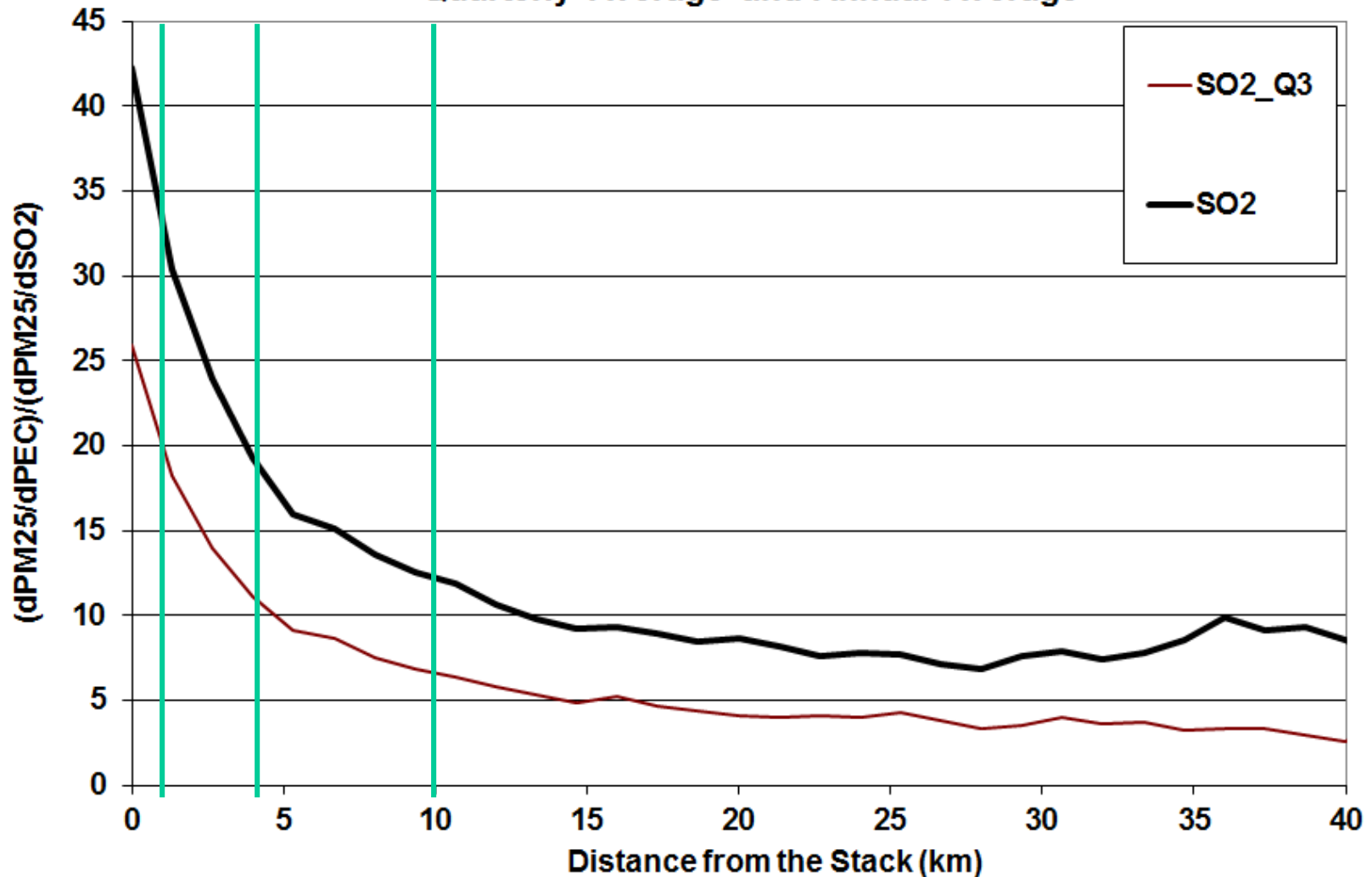
Q2 SO₂ Offset Ratios

SO₂ Trading Ratio at 1.333 km Domain
Quarterly Average and Annual Average



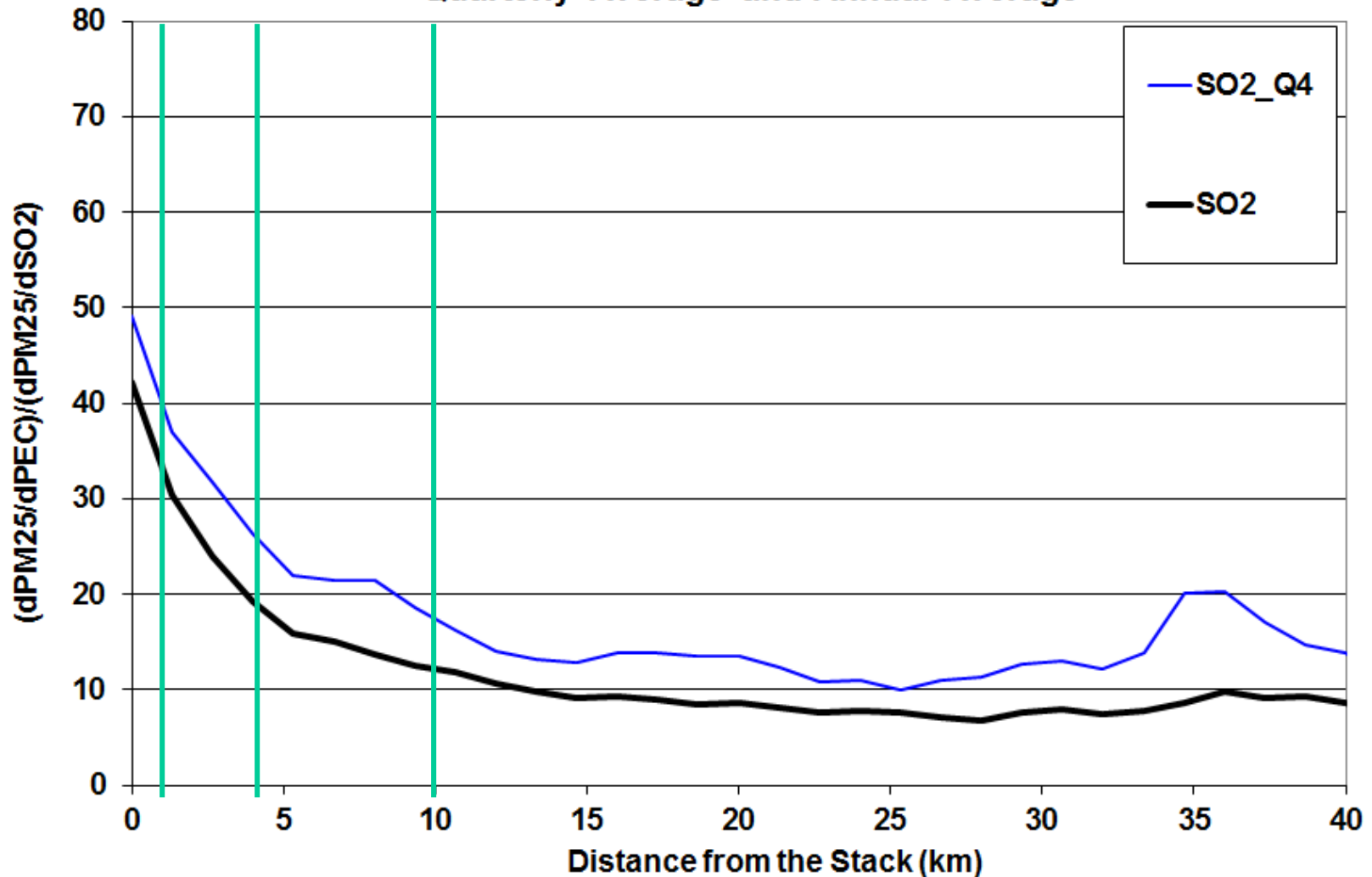
Q3 SO₂ Offset Ratios

SO₂ Trading Ratio at 1.333 km Domain
Quarterly Average and Annual Average



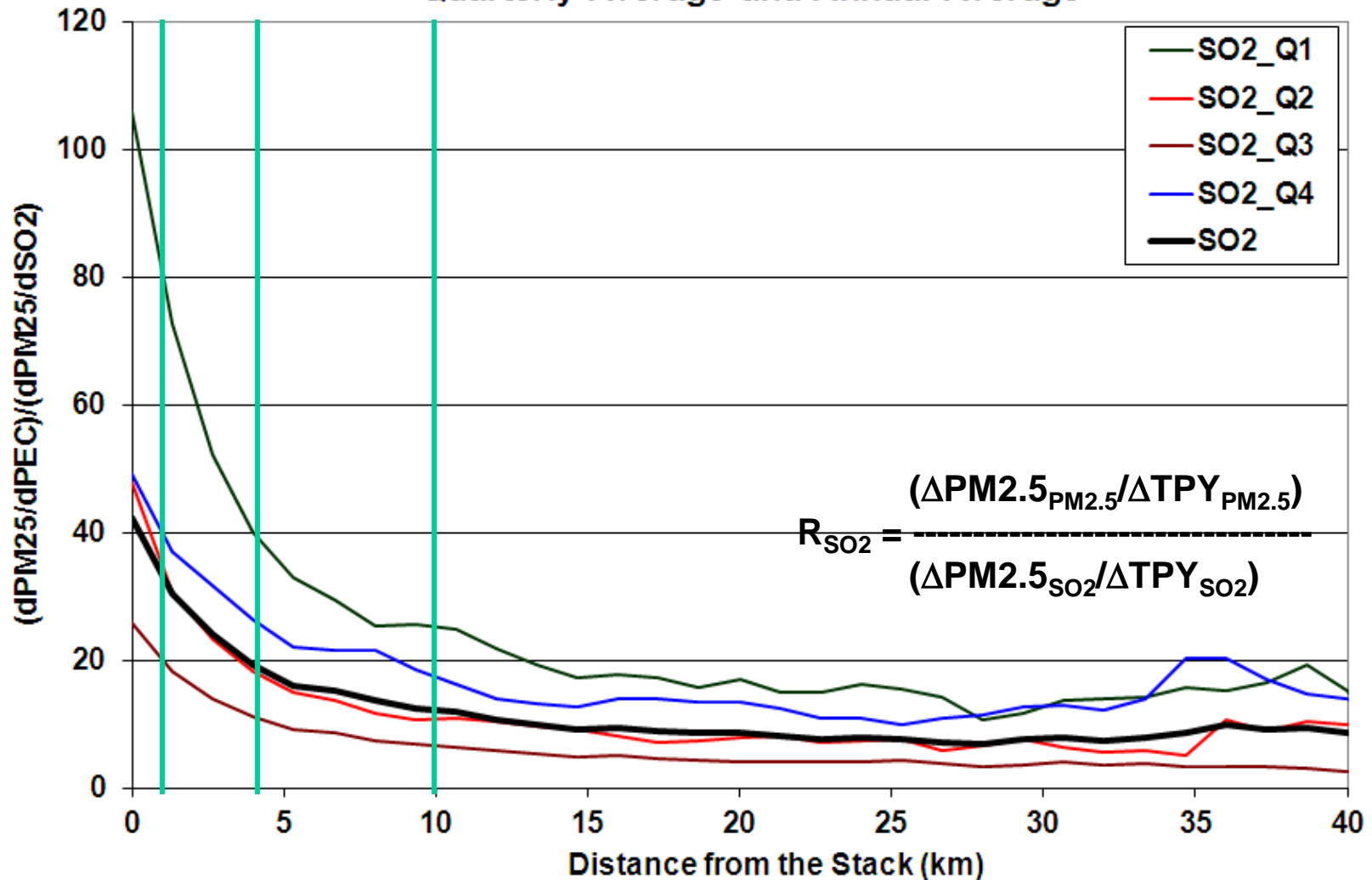
Q4 SO₂ Offset Ratios

SO₂ Trading Ratio at 1.333 km Domain
Quarterly Average and Annual Average



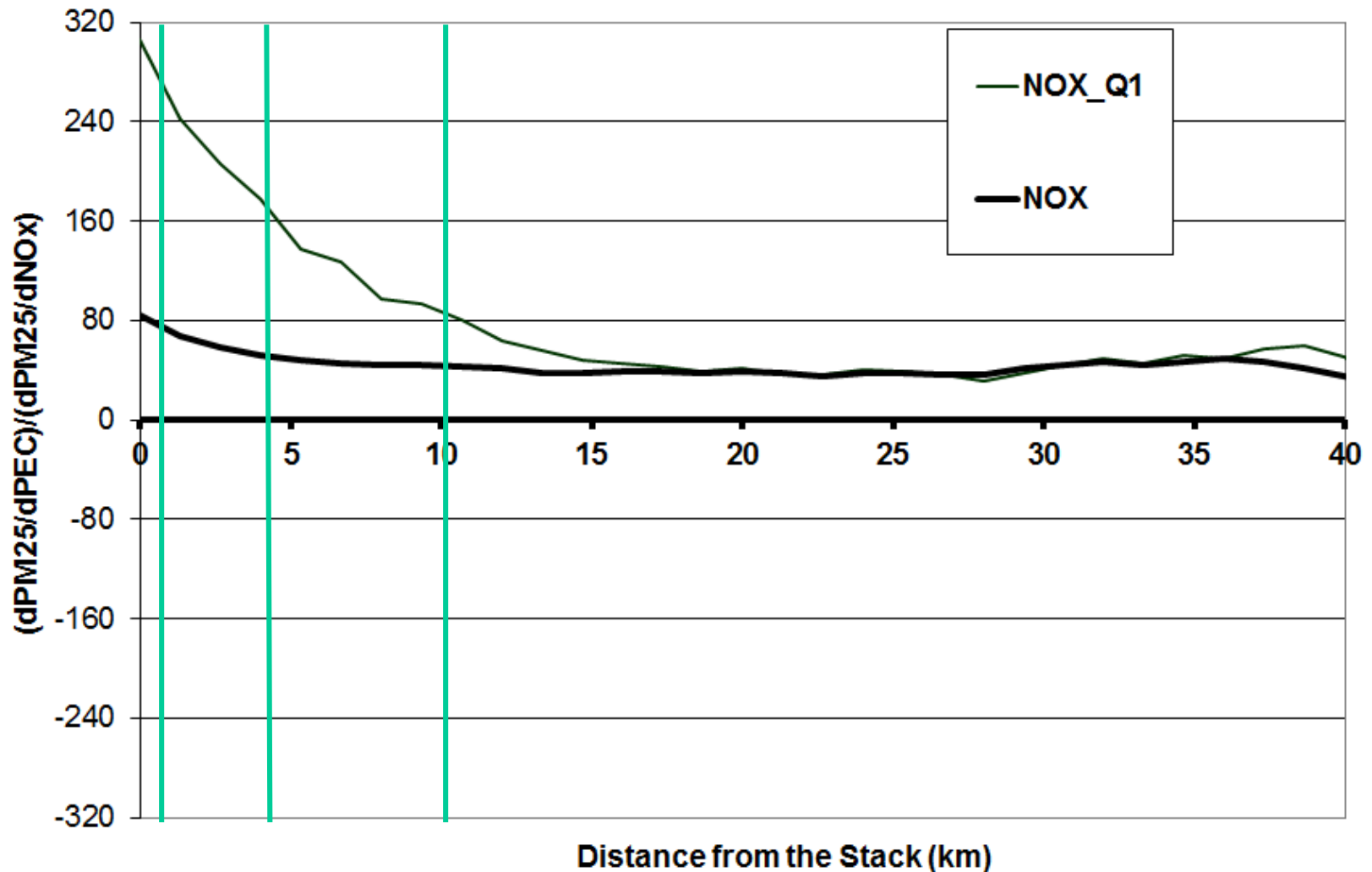
Quarterly SO₂ Offset Ratios

SO₂ Trading Ratio at 1.333 km Domain
Quarterly Average and Annual Average



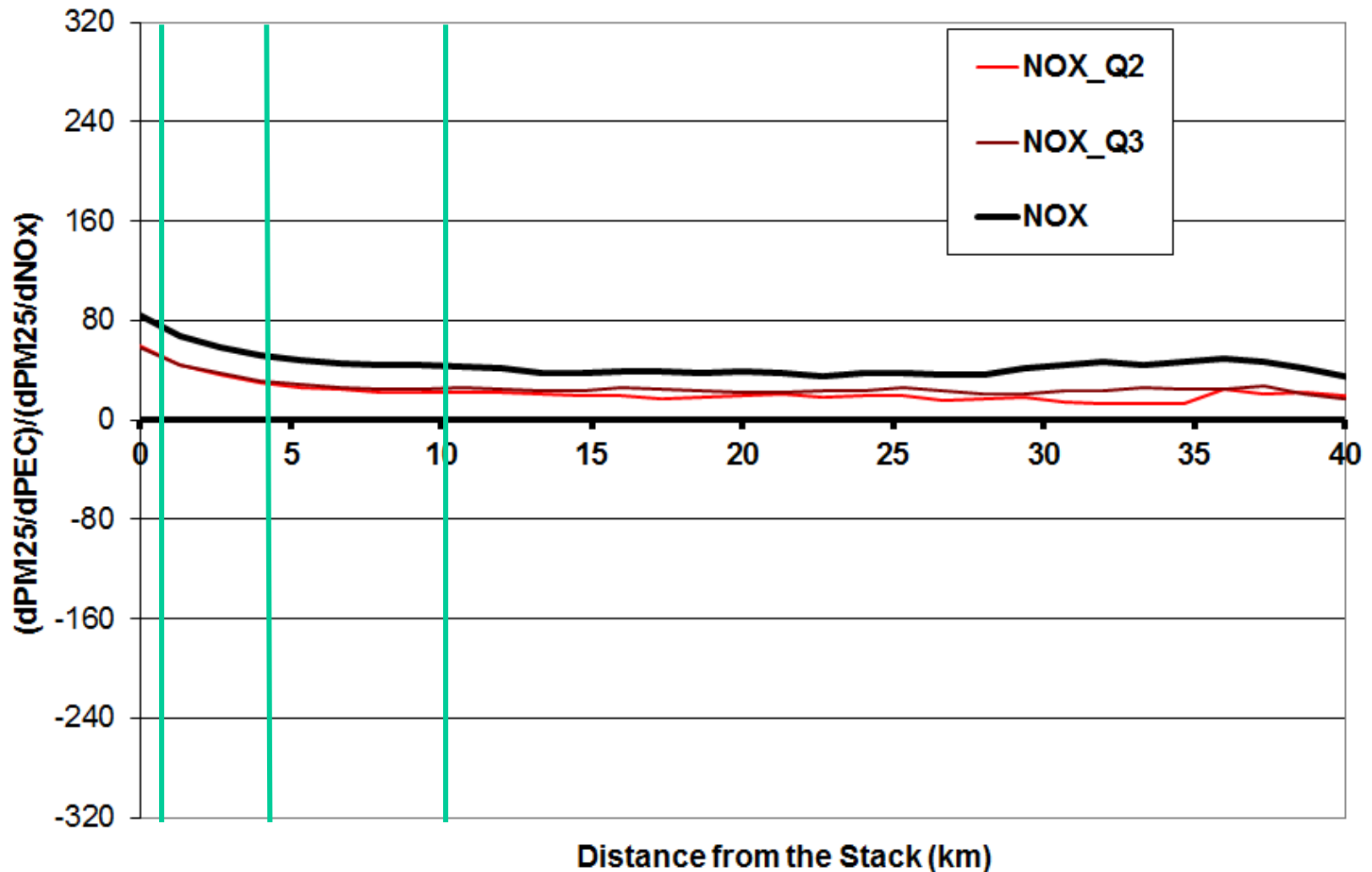
Q1 NOx Offset Ratios

NOx Offset Ratio at 1.333 kmDomain
Quarterly Averages and Annual Average



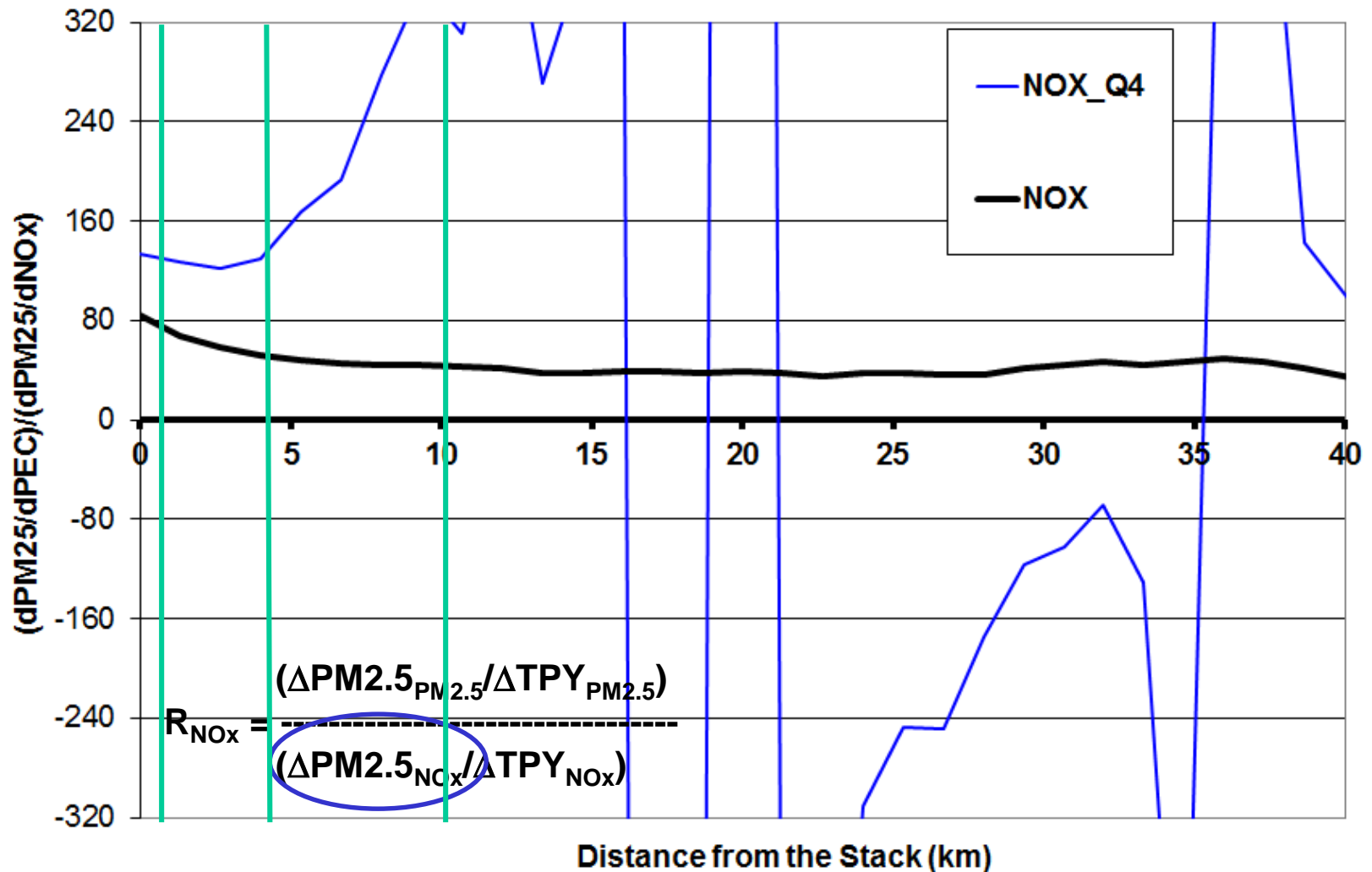
Q2 and Q3 NOx Offset Ratios

NOx Offset Ratio at 1.333 kmDomain
Quarterly Averages and Annual Average



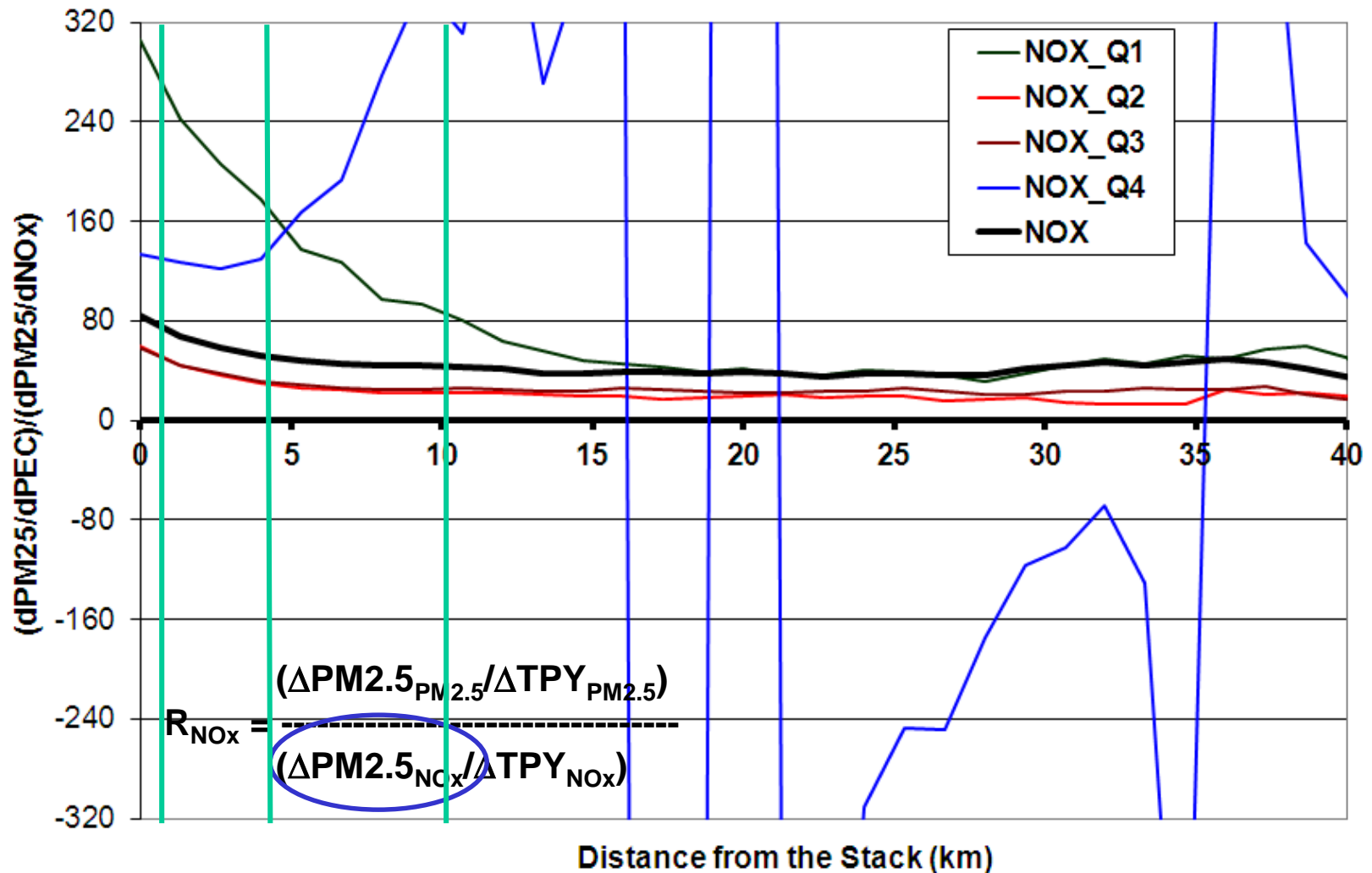
Q4 NOx Offset Ratios

NOx Offset Ratio at 1.333 kmDomain
Quarterly Averages and Annual Average



Quarterly NOx Offset Ratios

NOx Offset Ratio at 1.333 kmDomain
Quarterly Averages and Annual Average



Impacts of Season of Year

- SO₂ and NO_x offset ratios vary by season of the year and distance from the source:

SO₂ Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	15:1	7:1	5:1	10:1

NO_x Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	120:1
> 10 km	40:1	20:1	20:1	N/A

Impact of Stack Height

- Stack height has a small impact on the SO₂ offset ratios.
- Stack height has a bigger impact on NO_x offset ratios.
- Shorter stacks have higher offset ratios (less PM_{2.5} formation), so using the lower offset ratios is conservative.
- Taller stacks will be limited by GEP Stack Height Regulations, so we will not need to adjust the ratios.

Impacts of Grid Resolution

- Larger grid resolutions (e.g., 12 km) produce more conservative SO₂ and NO_x offset ratios (lower ratios) compared to smaller grid resolutions (e.g., 1.3 km) near the source.
- Larger grid resolutions produce similar SO₂ and NO_x offset ratios compared to smaller grid resolutions far from the source.
- Creating SO₂ and NO_x offset ratios using larger grid cells is a conservative approach.

Impact of Location

- Downtown Atlanta and west Georgia are currently being analyzed.
 - West Georgia looks very similar to current location
 - Downtown Atlanta gives higher offset ratios (less secondary PM_{2.5})
- Will perform sensitivity runs for five additional locations in Georgia
- Will either pick the most conservative trading ratios by looking at variations across the state or provide trading ratios that vary by region of the state.

Tiered Approach

- Use tiered approach starting with the most conservative offset ratios and easiest to apply:
 - Tier 1
 - SO₂ and NO_x ratios from Q3 at $d > 10$ km
 - Tier 2
 - SO₂ and NO_x ratios from Q3, vary with distance
 - Tier 3
 - SO₂ and NO_x ratios by quarter at $d > 10$ km
 - Tier 4
 - SO₂ and NO_x ratios by quarter, vary with distance

Tier 1

SO₂ Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	15:1	7:1	5:1	10:1

NO_x Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	120:1
> 10 km	40:1	20:1	20:1	N/A

Tier 1 “equivalent” direct PM_{2.5} emissions from SO₂ and NO_x can be accounted for by scaling the standard AERMOD output files.

Tier 2

SO₂ Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	15:1	7:1	5:1	10:1

NO_x Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	120:1
> 10 km	40:1	20:1	20:1	N/A

Tier 2 “equivalent” direct PM_{2.5} emissions from SO₂ and NO_x can be accounted for by scaling the standard AERMOD output files.

Tier 3

SO₂ Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	15:1	7:1	5:1	10:1

NO_x Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	120:1
> 10 km	40:1	20:1	20:1	N/A

Tier 3 “equivalent” direct PM_{2.5} emissions from SO₂ and NO_x should be added to the actual direct PM_{2.5} emissions prior to running AERMOD.

Tier 4

SO₂ Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	15:1	7:1	5:1	10:1

NO_x Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	120:1
> 10 km	40:1	20:1	20:1	N/A

Tier 4 “equivalent” direct PM_{2.5} emissions from SO₂ and NO_x will require scaling quarterly AERMOD outputs followed by recalculation of annual and daily PM_{2.5} impacts.

Example PSD Application

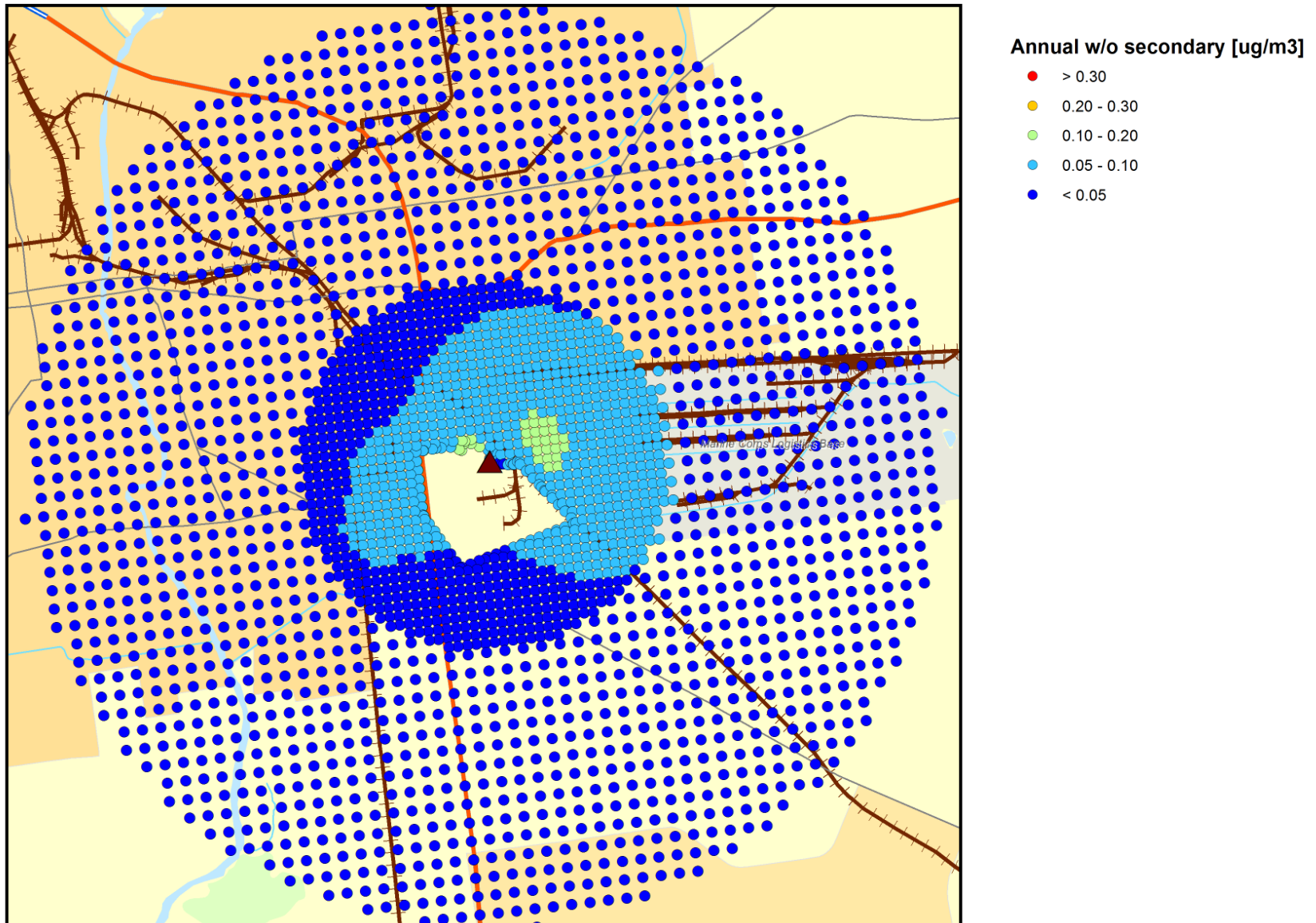
- Direct PM2.5 emissions = 118.30 TYP
- SO2 emissions = 190.93 TPY
- NOx emissions = 340.65 TPY
- PM2.5 Scaling Factor =
$$\frac{(\text{SO2 TPY} / \text{SO2 Ratio}) + (\text{NOx TPY} / \text{NOx Ratio}) + \text{PM2.5 TPY}}{\text{PM2.5 TPY}}$$

Distance	Q3 SO2 Ratio	Q3 NOx Ratio	Scaling Factor
< 1 km	20	50	1.138
1 - 4 km	10	35	1.244
4 - 10 km	7	20	1.375
> 10 km	5	20	1.467

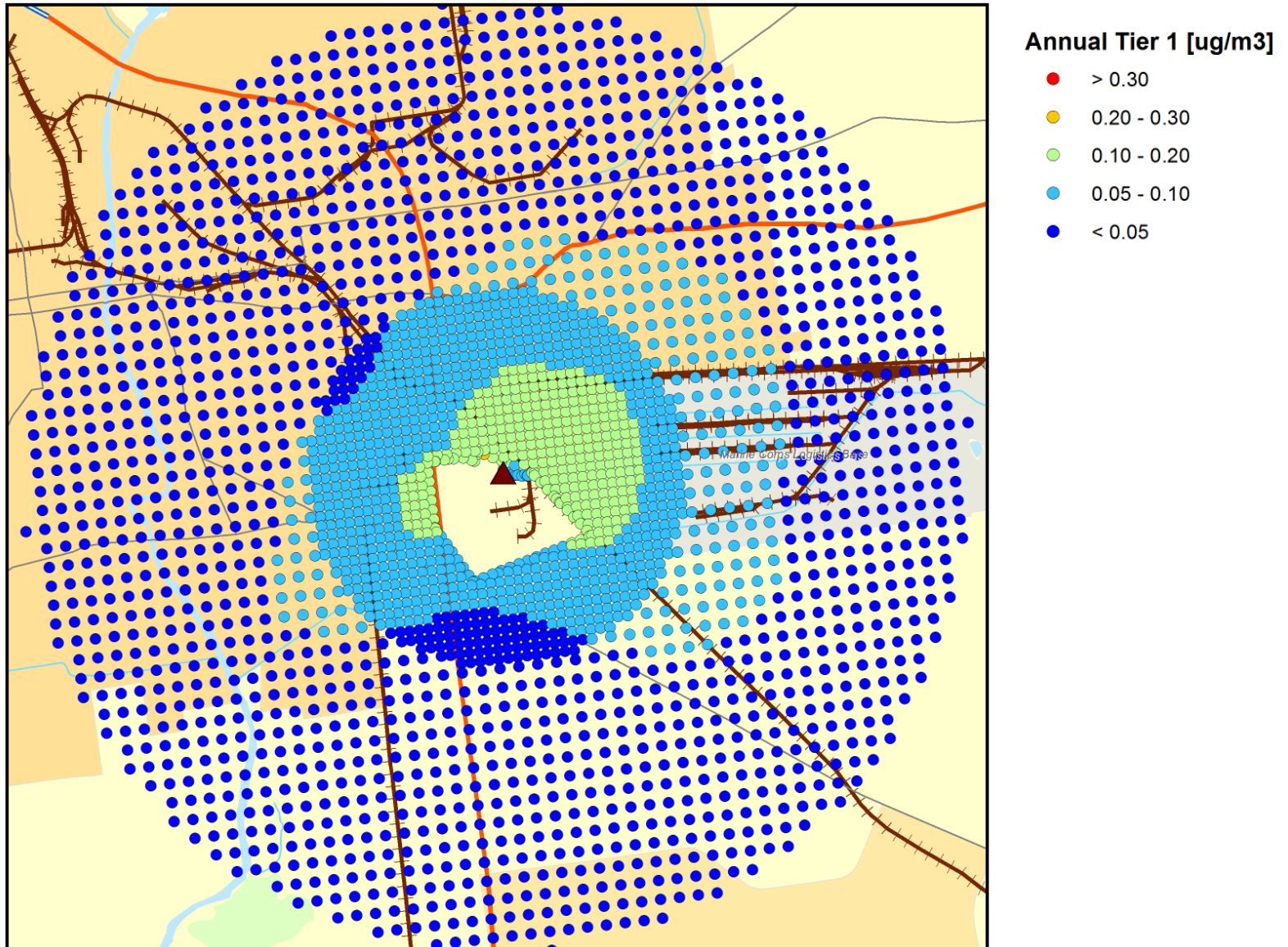
(Tier 2)

(Tier 1)

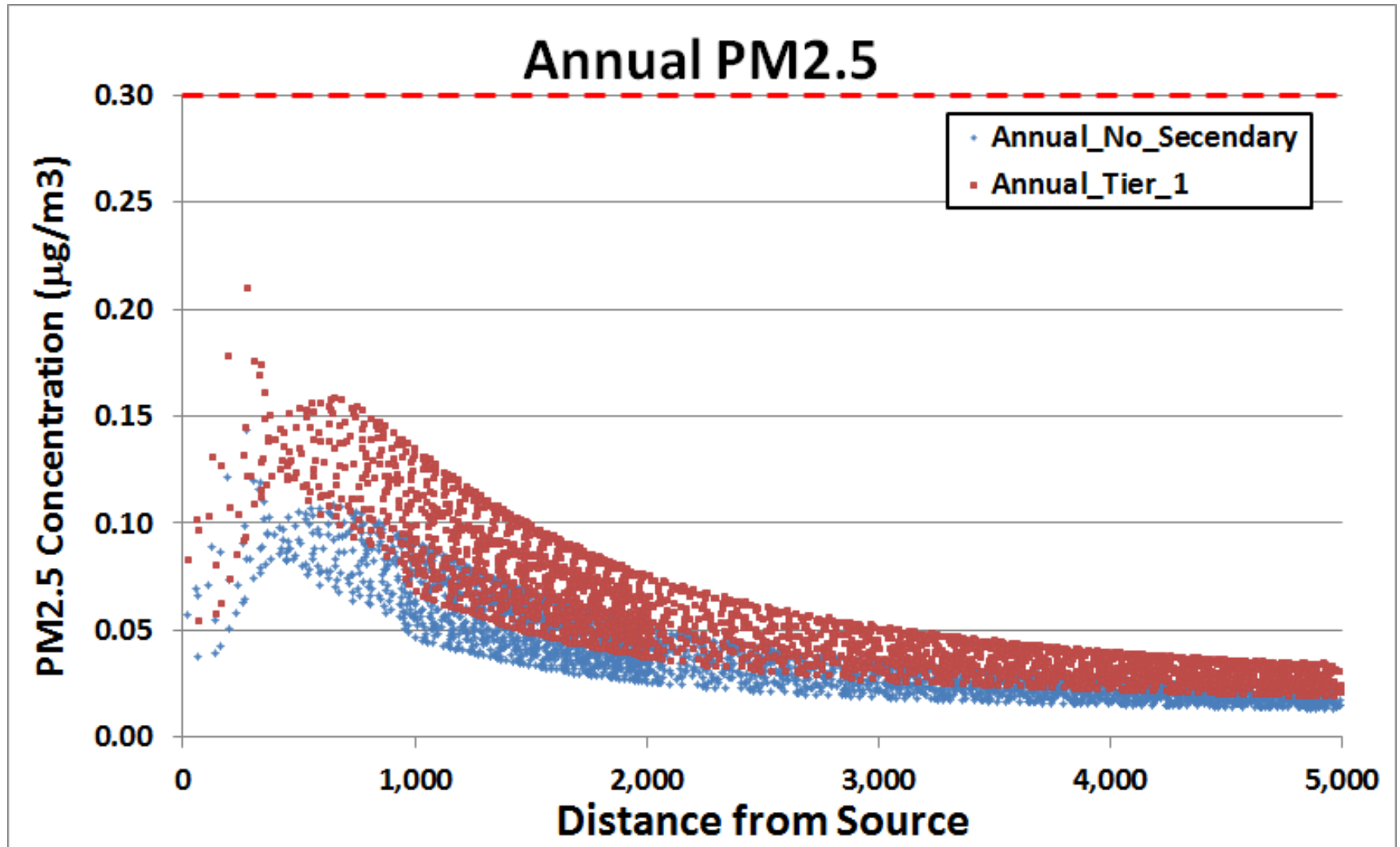
Annual PM2.5 – No Secondary



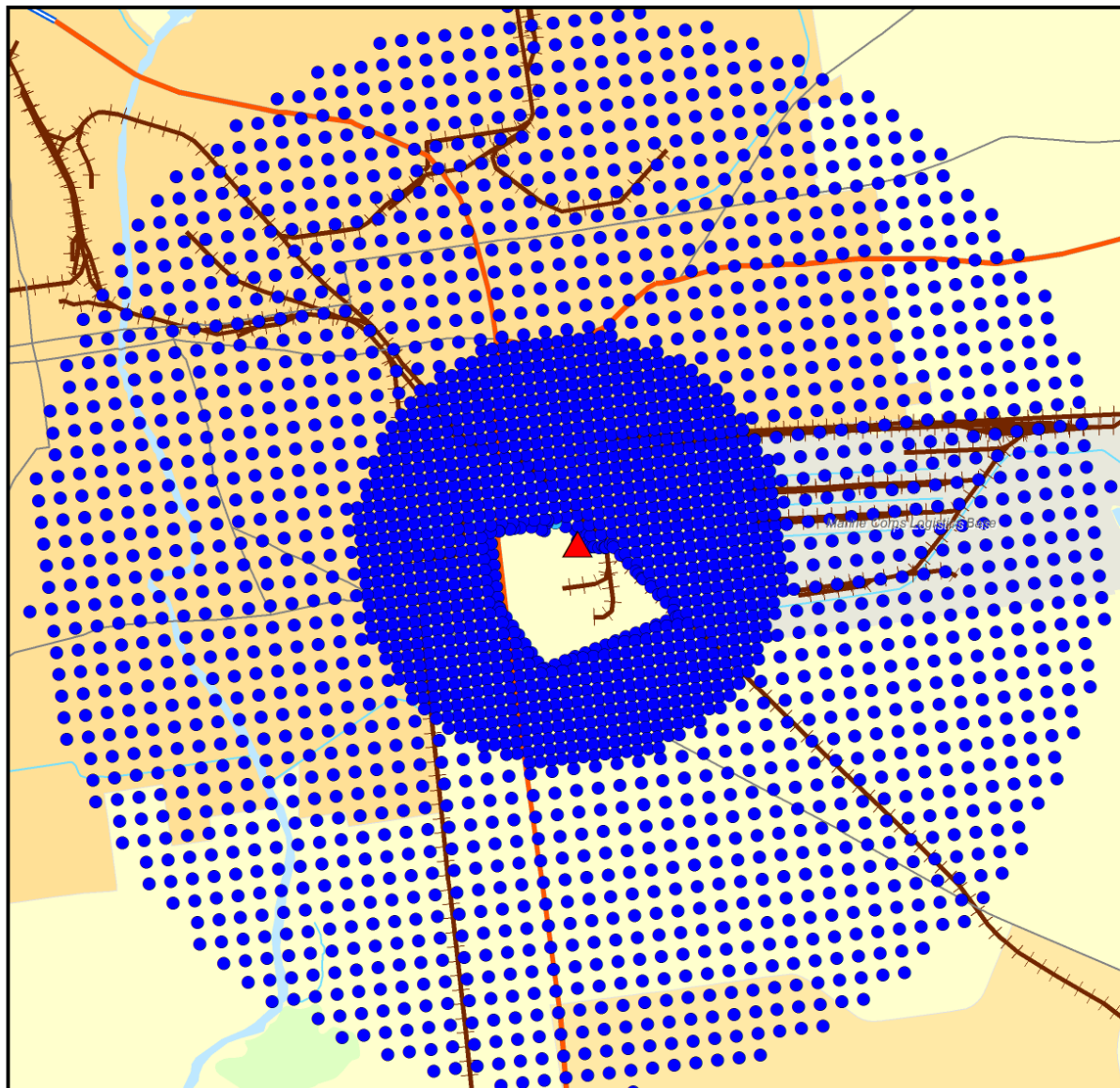
Annual PM2.5 – Tier 1



Annual PM2.5 vs. SIL



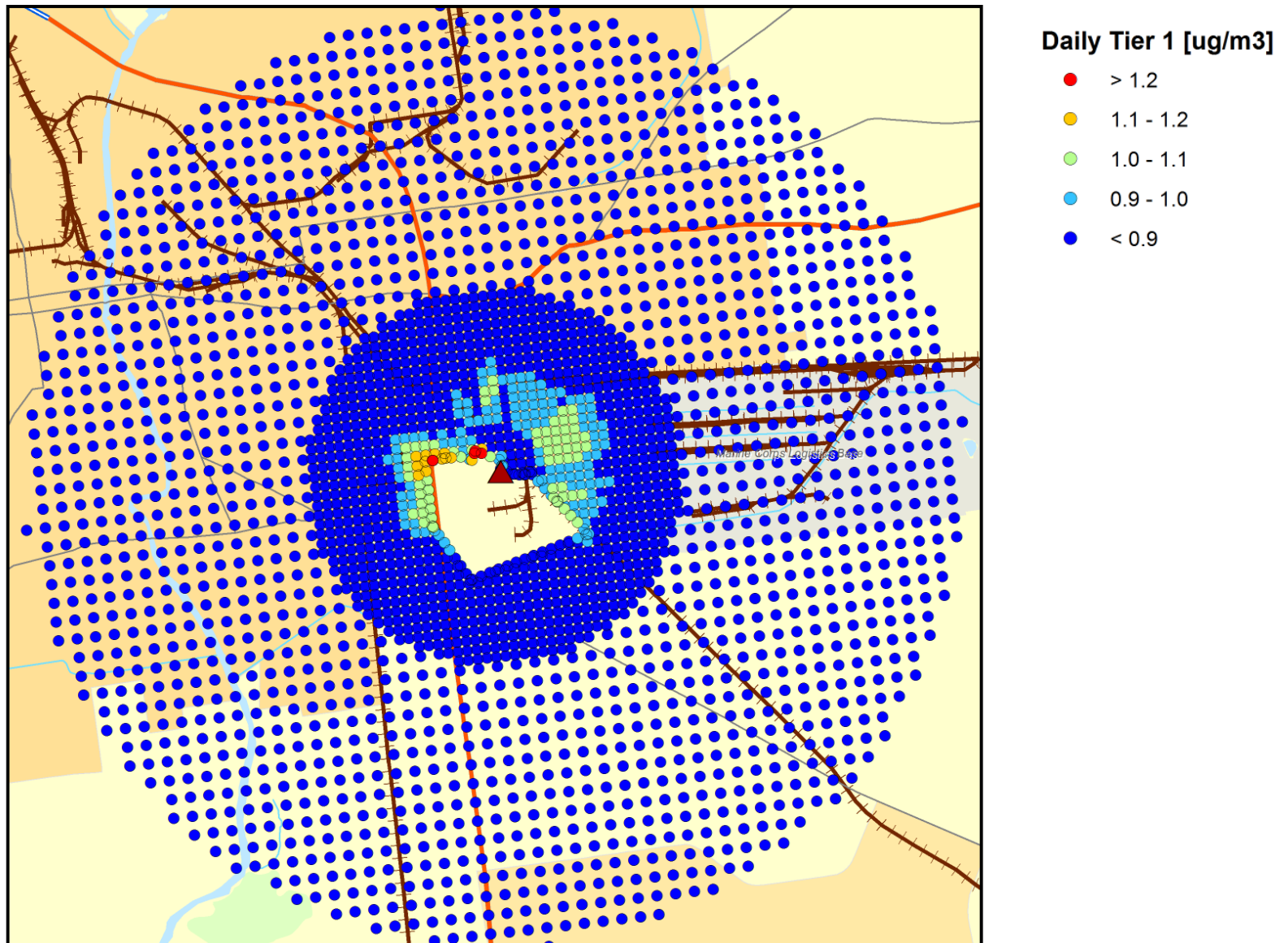
Daily PM2.5 – No Secondary



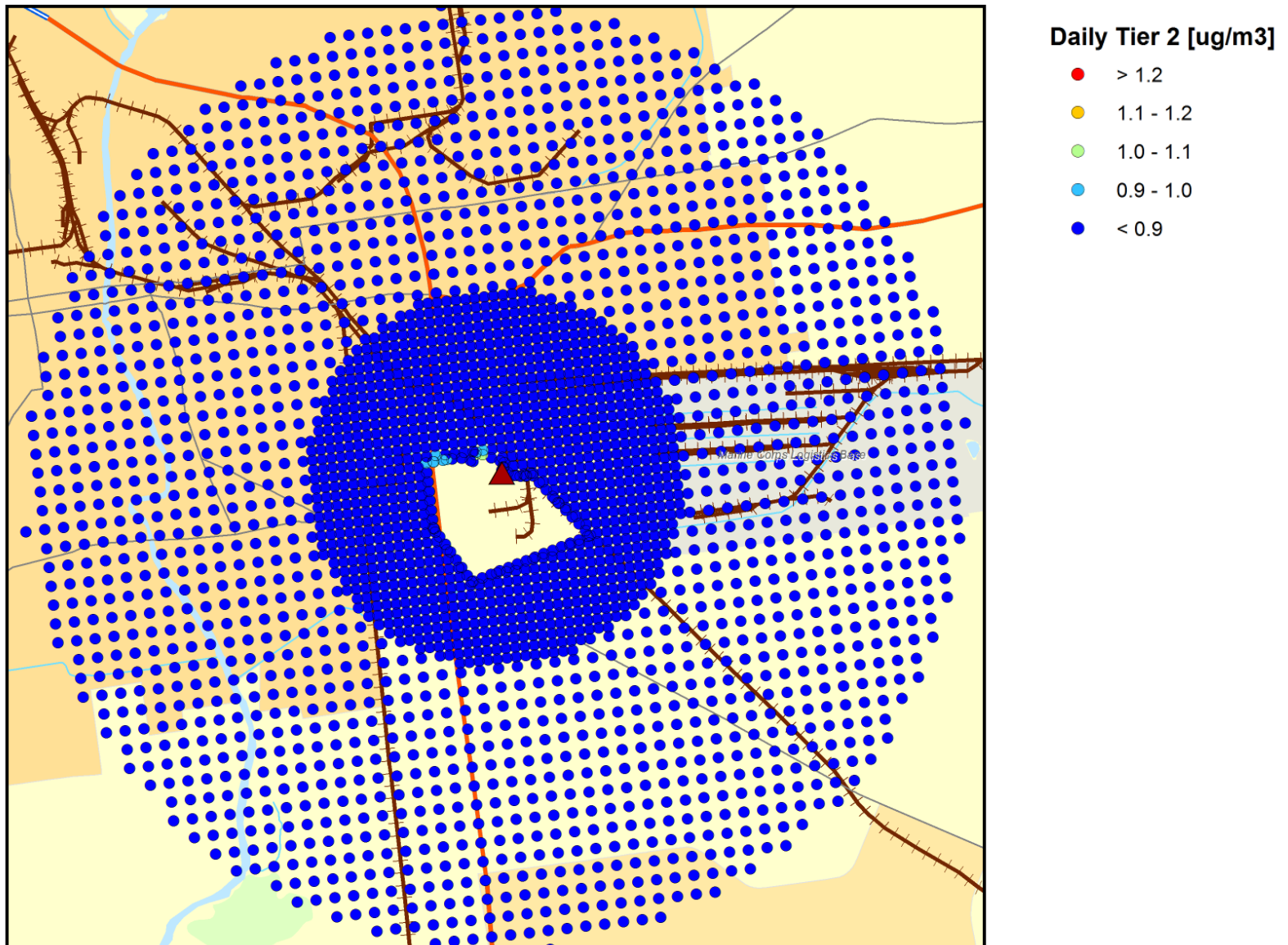
Daily w/o secondary [ug/m3]

- > 1.2
- 1.1 - 1.2
- 1.0 - 1.1
- 0.9 - 1.0
- < 0.9

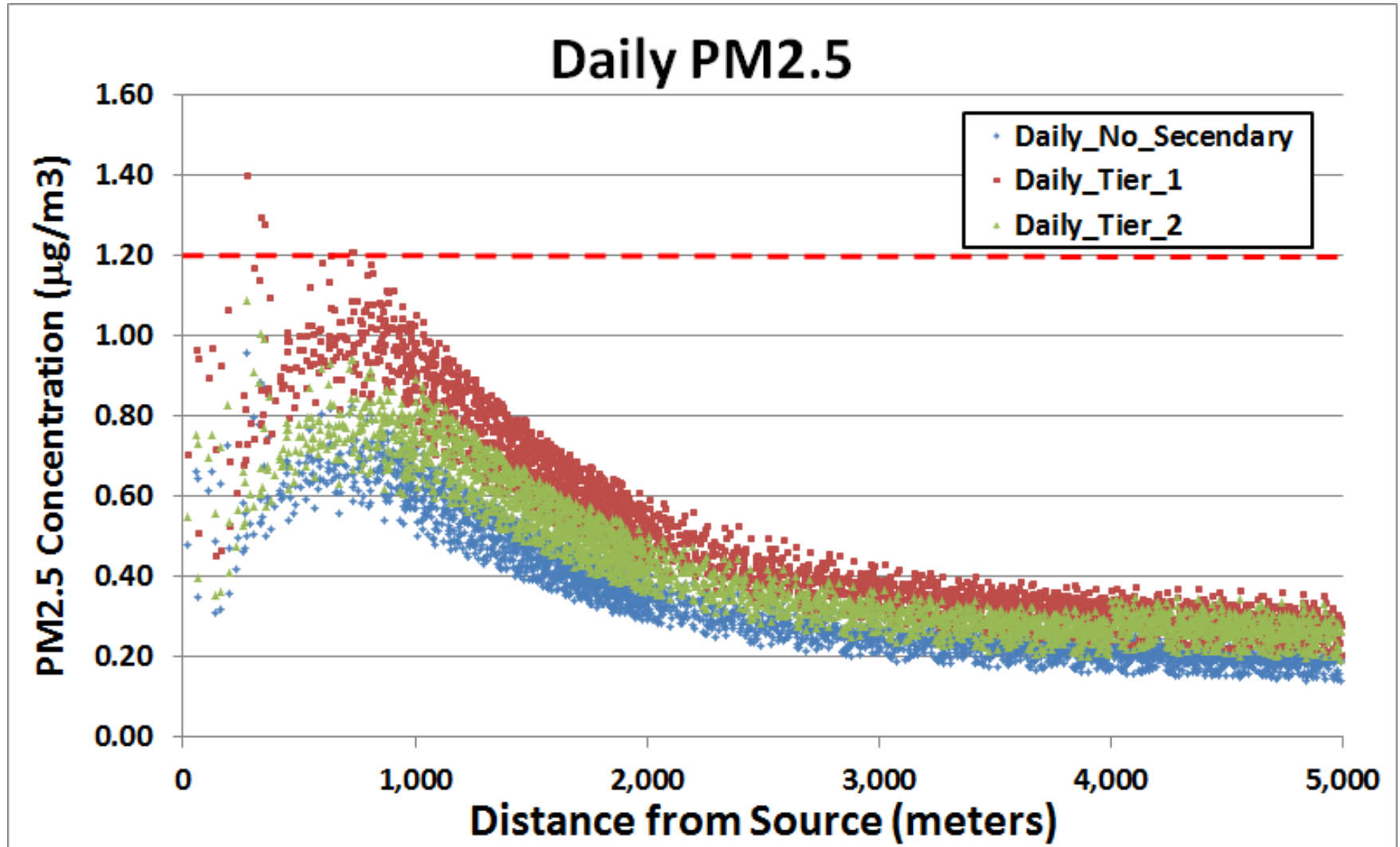
Daily PM2.5 – Tier 1



Daily PM2.5 – Tier 2



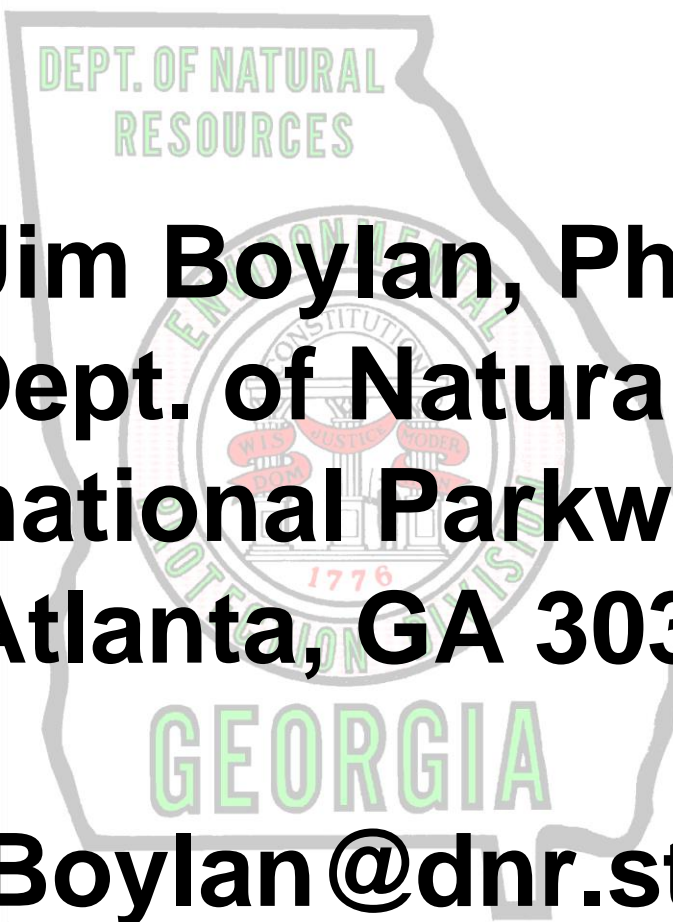
Daily PM2.5 vs. SIL



Next Steps

- Perform Tier 3 and Tier 4 calculations for example PSD application.
- Evaluate SO₂ and NO_x offset ratios for other locations in Georgia.
- Document approach and final offset ratios so applicants can use them in Georgia PSD applications.
- Repeat the analysis with new 2011/2018 modeling platform.

Contact Information



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